Psychometric Comparisons of 3 Functional Ambulation Measures for Patients With Stroke

Jau-Hong Lin, PhD; Miao-Ju Hsu, PhD; Hsin-Wen Hsu; Hung-Chia Wu, MS; Ching-Lin Hsieh, PhD

Background and Purpose—We compared the test–retest reliability, validity, and responsiveness of the Dynamic Gait Index, the 4-item Dynamic Gait Index, and the Functional Gait Assessment for assessment of walking in patients with stroke.

Methods—Forty-five outpatients participating in the validity and responsiveness study were tested using the 3 walking measures as well as the 10-m walk test, Barthel Index, and Postural Assessment Scale for Stroke Patients. We tested them during the first week, then again after 2 months and 5 months of therapy. Another 48 chronic patients completed the 3 measures twice, 1 week apart, in the test–retest reliability study.

Results—Thirty-five participants completed 3 time-point assessments. The Functional Gait Assessment showed the least floor and ceiling effects, indicating it has the best discriminative ability for patients with stroke with high walking function. We found the 3 measures were highly correlated with each other, indicating excellent concurrent validity, and all measures at the first week of therapy were moderately to highly correlated with the Barthel Index scores at 5 months, indicating good predictive validity. Responsiveness of the 3 measures was moderate during a 5-month period, and all showed good test–retest reliability. The minimal detectable changes between tests indicate acceptable random error.

Conclusions—All 3 measures showed sufficient validity, responsiveness, and reliability for assessment of walking function in patients with stroke undergoing rehabilitation, but the Functional Gait Assessment is recommended for its psychometric properties. (Stroke. 2010;41:2021-2025.)

Key Words: gait ■ psychometrics ■ stroke

Over 60% of acute stroke survivors are unable to walk or need assistance/intervention in walking.1 Impaired ambulation is greatly associated with fall risks, dependency, limited participation in social activities, and poor quality of life.2 Thus, recovery of ambulation is 1 of the most desired goals for stroke survivors undergoing rehabilitation.3 For clinicians to develop protocols for ambulation rehabilitation and monitor change of ambulation function (outcome measurement) in patients with stroke, a reliable, valid, and responsive measure is fundamental.4

In clinical settings, walking function is commonly assessed as part of activity measures such as the Barthel Index, Functional Independent Measure, or Functional Ambulation Classification. However, these measures provide limited walking information for treatment planning and outcome measurement. Fixed-distance or timed walking tests (eg, the 10-m walk test and 6-minute walk test) render quantified walking information and are commonly used for monitoring improvement or outcome measurement. However, these tests cannot provide useful information (eg, walking problems) for designing rehabilitation protocols aiming at improving ambulation function.

The Dynamic Gait Index (DGI) was developed to capture walking problems in maintaining stability during gait activities and determine falls risk in older people.5 The DGI contains 8 walking tasks, which measure walking over various surfaces at the same time as changing speed and turning the head, walking with a pivot turn, walking over and around obstacles, and stair climbing. Thus, the test results can help clinicians determine a patient’s difficulties in ambulation and design a treatment protocol. The DGI has been validated in older people and patients with vestibular dysfunction or stroke.6–8 However, a ceiling effect of the DGI in patients with vestibular disorders has been reported.9 Wrisley et al10 created the 10-item Functional Gait Assessment (FGA) on the basis of the DGI and increased the challenge of the assessment so that the test would be sufficiently sensitive to monitor changes for patients with high ambulation function. More recently, Marchetti and Whitney11 shortened the DGI to 4 items (DGI-4). The psychometric properties of the DGI-4 are described in detail in the article above.
The PASS contains 12 items assessing balance ability in maintaining posture or changing postures. Its total score ranges from 0 to 36. The psychometric properties of the PASS are satisfactory in patients with stroke. The BI is a measure of the basic activities of daily living function. Its score ranges from 0 to 20. The reliability, validity, and responsiveness of the BI are sufficient in patients with stroke.

**Statistical Analysis**

**Distribution**

The score distribution of the 3 measures was examined. The floor effect is the percentage of the sample scoring the minimum possible scores. The ceiling effect represents the opposite extreme.

**Validity**

Convergent validity was assessed by examining the relationships between patients’ DGI/DGI-4/FGA scores and contemporaneous results for the 10MWT and PASS at the 3 time points of outpatient therapy using the Spearman ρ correlation coefficients. Predictive validity of the 3 measures was assessed by correlating DGI/DGI-4/FGA scores at the first week of outpatient therapy with the BI scores at 5 months of outpatient therapy using Spearman ρ. The low, fair, moderate, and high correlations were defined as a ρ between 0 and 0.25, between 0.25 and 0.5, between 0.5 and 0.75, and >0.75, respectively.

**Responsiveness**

Two approaches were used to examine the responsiveness of the 3 measures at 2 time periods: the first week to 2 months of therapy and >5 months of therapy. First, effect size d was defined as the observed mean change scores divided by the SD of the baseline score. An effect size d >0.8 was large, 0.5 to 0.8 was moderate, and 0.2 to 0.5 was small. Second, we used the Wilcoxon matched-pairs signed-rank tests to determine the statistical significance of the change scores.

**Reliability**

The test–retest reliability of the 3 measures was analyzed with the intraclass correlation coefficient (ICC). We used the 2-way random effects model of the ICC to determine the level of agreement between test–retest assessments. ICC values ≥0.80 indicate high agreement.

We also quantified random measurement errors using the SEM (ie, SD of all test–retest scores)×√(1−ICC)). The minimal detectable change (MDC=1.96×SEM×√(2)) is used as a threshold to determine whether the change score of an individual patient is real at the 95% confidence level. The MDC value of a measure was considered acceptable when the MDC was <20% of the maximum score of the measure.

**Results**

Forty-five patients met the selection criteria and participated in the validity and responsiveness study. Most of those excluded had a recurrent stroke or could not follow instructions. They had stroke for durations ranging from 3 to 36 months with a median of 9 months. Ten patients were lost to follow-up because of returning to work, having a recurrent stroke, or declining further participation. Thirty-five participants completed all 3 assessments. Compared with the individuals who dropped out, the participants who completed 3 assessments did not show significant differences in terms of demographic characteristics and functional ambulation (P>0.42). Most patients had mild to moderate disability. Table 1 shows further characteristics of the participants.

The FGA had the least ceiling effects (0.0% to 5.7%) as compared with the >10.0% of the participants achieving

<table>
<thead>
<tr>
<th>Subject</th>
<th>Method</th>
<th>Procedures</th>
<th>Measures</th>
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| The study protocol consisted of 2 parts. First, the validity and responsiveness were tested on patients with stroke undergoing outpatient rehabilitation at the E-Da Hospital from January 1, 2008, to September 30, 2009. Patients were included in this study if they met the following criteria: (1) diagnosis of cerebral hemorrhage or cerebral infarction; (2) first onset of stroke without other major diseases (eg, cancer, dementia) and absence of pre-existing disability; (3) ability to follow instructions and walk on level surfaces for at least 10 m with or without a device; and (4) provision of informed consent. The second part of the study examined test–retest reliability. We recruited another independent sample of chronic patients undergoing outpatient rehabilitation at the Kaohsiung Municipal Hsiao-Kang Hospital. The selection criteria were the same as those in the first part of the study, except that the time since stroke onset was >1 year. Patients were excluded for the following reasons: medical instability, inability to ambulate, or cognitive impairment. This study received approval from the ethical review committee at the hospital (KMUH-IRB-940154).

In the validity and responsiveness study, the DGI, the DGI-4, and the FGA were administered to patients undergoing outpatient therapy by a trained physiotherapist at the first week, 2 months, and 5 months of outpatient therapy. For the test–retest reliability study, the other physiotherapist administered the DGI, the DGI-4, and the FGA twice on patients with the tests conducted 1 week apart. The demographic details and major comorbidity data of the patients were collected from medical records.

The DGI consists of 8 items, including walking, walking at the same time as changing speed, walking at the same time as turning the head horizontally and vertically, walking with a pivot turn, walking over and around obstacles, and stair climbing. The items are scored on a 4-point scale from 0 to 3. The sum score ranges from 0 to 24.

The DGI-4 has 4 test items: gait level surface, change in gait speed, and gait with horizontal and vertical head turns. The sum score is from 0 to 12.

The FGA is a 10-item test that contains 7 of the 8 items (except walking around obstacles) from the DGI and 3 additional tasks, including walking with a narrow base of support, walking with the eyes closed, and ambulating backward. The total score ranges from 0 to 30.

The 10MWT was administered by marking a start and an end point with the distance between the 2 points being 10 m. Patients were asked to stand behind the start point and to walk at a comfortable pace until they crossed the end point.

appear superior or equivalent to those of the 8-item test in people with balance and vestibular disorders. However, it is still unknown whether the DGI-4 has better psychometric properties than the DGI or the FGA in patients with stroke.

The 3 functional ambulation measures (the DGI, the DGI-4, and the FGA) provide unique information on walking quality in patients with stroke, and thus they show great potential for treatment planning, identification of fall risk, and outcome measurement. However, the psychometric properties of the 3 measures have not been compared, which limits their use in both clinical and research settings. Therefore, we compared the reliability, validity, and responsiveness of the 3 measures in patients with stroke.
highest scores on both the DGI and DGI-4 at some time points (Table 2).

The 3 measures were highly correlated with each other at the 3 time points (Spearman \( r > 0.91 \)). The scores of 3 measures were moderately to highly correlated with those of the 10MWT (absolute Spearman \( r = 0.61 \) to 0.87) and the PASS (Spearman \( r = 0.74 \) to 0.85) at the 3 time points (Table 3). The scores of the 3 measures at the first week of therapy were moderately correlated with those of the BI scores at 5 months of therapy (\( r = 0.75, 0.59, 0.72 \), respectively).

Table 4 shows that the 3 measures had low to moderate responsiveness (effect size \( d = 0.47 \) to 0.68) in detecting changes during the 5-month period. The changes of the 3 measures were all significant (\( P < 0.01 \)).

The other 48 chronic patients participated in the test–retest reliability study. This sample consisted of 20 women and 28 men with a mean age of 54.9 years (SD = 10.2). Of these chronic patients, 27 (56%) were diagnosed with stroke infarction, and 21 (44%) had right hemiplegia.

Table 5 shows that test–retest reliability was high for the 3 measures (ICCs \( \geq 0.94 \) and lower limits of 95% CI \( \geq 0.90 \)).

### Discussion

This study is the first to concurrently compare the psychometric properties of the DGI, DGI-4, and FGA in samples of outpatients with stroke to assess how appropriate the 3 measures are for clinical and research use in outpatient rehabilitation. Our findings provide an empirical basis on which clinicians and researchers may evaluate walking function during gait tasks and select functional ambulation measures for patients at recovery stages after stroke.

Score distributions of the 3 measures at recovery stages for patients with stroke have not been reported in previous studies.\(^8,12\) However, such information is important in determining whether a measure assesses only a restricted functional range of patients with stroke. Whitney et al reported that the DGI showed notable ceiling effects in 247 patients with vestibular dysfunction.\(^9\) We found that the FGA demonstrated less ceiling effects than the other 2 measures. These results indicate that the FGA has the best discriminative ability for patients with stroke with high walking function.

The validity of a measure is of critical importance because it represents whether the measure assesses what it intends to measure. Jonsdottir and Cattaneo reported that the concurrent validity of the DGI was confirmed by moderate to high correlating results to the timed walking test, the Timed Up and Go test, and the Activities-specific Balance Confidence Scale in patients with stroke.\(^8\) Thieme et al found that the FGA was moderately to highly associated with the Berg Balance Scale, 10MWT, and Functional Ambulatory Category in patients with subacute stroke.\(^12\) In our study, the associations between the 3 measures and 10MWT and PASS were moderate to high. Our results are generally in accordance with the findings of previous studies.\(^8,12\) These obser-
vations provide strong evidence of the validity of the 3 measures in assessing functional ambulation in patients with stroke.

Early prediction of a patient’s functional status is important for patient management. Hall et al found that the DGI score could be used to predict fall risk outcome at the beginning of rehabilitation. In our study, correlation among the scores of the 3 measures at the beginning of outpatient therapy and BI scores at 5 months of outpatient therapy were moderate, indicating that the 3 measures have satisfactory predictive validity on activities of daily living function. These findings further confirm the predictive validity and clinical use of the 3 measures.

Responsiveness is important for any measurement tool designed to evaluate change over time. To our knowledge, no study has examined the responsiveness of the 3 measures. We found that the 3 measures were equally sensitive to change during outpatient rehabilitation therapy. The 3 measures, in general, had moderate responsiveness in detecting change at the 5-month period of rehabilitation (at the beginning, at 2 months, and at 5 months of outpatient therapy). Our findings suggest that the 3 measures are able to detect changes in patients with stroke undergoing outpatient rehabilitation.

Test–retest agreement of the 3 measures was very high (ICC >0.92). These results are consistent with those reported in previous studies. These observations suggest that the 3 measures are highly reliable in monitoring the patients’ changes in functional ambulation when administered by trained raters. In addition, for estimating measurement error between repeated measurements, the MDC is used to examine the variability of the score caused by random measurement error for an individual. Both clinicians and researchers can use the MDC as a threshold to determine whether the change in score on a measure of an individual patient has reached a real improvement (or deterioration) or is due to random measurement error. Thus, the MDC of a measure is critical to the interpretation of data in clinical or research settings.

We found that the MDCs of the 3 measures were <20% of their corresponding highest scores, indicating acceptable levels of measurement error. Our findings suggest that a change of >4 points for the total scores of the DGI (highest possible score: 24), 3 points for the DGI-4, (12) and 5 points for the FGA (30) in each patient is not likely to be attributable to chance variation or measurement error and can be interpreted as a real change with 95% confidence.

Kinematic or kinetic analyses on walking function usually reveal more detailed information on gait characteristics than clinical measures such as the 3 measures used in this study. Marchetti et al investigated spatiotemporal characteristics of gait during performance of the DGI tasks in individuals with and without balance or vestibular disorders. They found that spatiotemporal characteristics of the DGI tasks appeared to be relatively reliable and distinguished participants with balance or vestibular disorders. These findings support that the DGI and the FGA (containing 7 of the 8 items of DGI) can be useful in assessing gait deviations and guiding intervention and outcome measurement. However, the spatiotemporal characteristics underlying the tasks of the 3 measures in patients with stroke remain to be investigated. Such studies would further confirm the use of the 3 measures for patients with stroke.

Two limitations of this study are addressed. First, all participants were ambulatory because the 3 measures were designed to assess functional ambulation. If the 3 measures are administered on patients with poor walking function, these measures might suffer a floor effect (ie, poor discriminative ability), and their responsiveness would be compromised. Second, our sample was a bit younger than the average age of stroke onset in Taiwan. The possible reason is that we did not recruit severe patients, who could not walk or follow instructions. Therefore, the results of this study are only generalizable to a similar population.

In summary, the 8-item DGI, the 4-item DGI, and the 10-item FGA showed sufficient validity, responsiveness, and reliability for patients with stroke undergoing rehabilitation. The FGA showed the least ceiling effects among the 3 measures, and thus the FGA is recommended for both clinicians and researchers.

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References

Table 5. Test–Reetest Reliability of the DGI, DGI-4, and FGA

<table>
<thead>
<tr>
<th>Measure</th>
<th>ICC (95% CI)</th>
<th>MDC</th>
<th>MDC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGI</td>
<td>0.94 (0.90–0.97)</td>
<td>4.0</td>
<td>16.6%</td>
</tr>
<tr>
<td>DGI-4</td>
<td>0.92 (0.87–0.96)</td>
<td>2.3</td>
<td>18.8%</td>
</tr>
<tr>
<td>FGA</td>
<td>0.95 (0.91–0.97)</td>
<td>4.2</td>
<td>14.1%</td>
</tr>
</tbody>
</table>
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